OPTIMIZATION OF PROCESSING PARAMETER FOR RECYCLED POLYPROPYLENE-NANOCLAY ON TENSILE STRENGTH

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Abstrak

Cetakan injeksi adalah salah satu proses paling efisien dalam produksi massal yang dapat dengan mudah menghasilkan produk dengan geometri yang akurat dengan waktu siklus yang sangat singkat. Tujuan utama dari penelitian ini adalah untuk menganalisis pengaruh parameter pemrosesan terhadap kualitas produk melalui percobaan ini, parameter yang akan digunakan adalah suhu leleh, tekanan pengepakan, kecepatan sekrup, dan waktu pengisian. Bahan-bahan yang akan digunakan dalam penelitian ini adalah polypropylene dan polypropylene-nanoclay daur ulang. Menurut hasil, 100% polypropylene memberikan nilai kekuatan tarik rata-rata sekitar 28,5 Mpa dengan parameter terbaik adalah suhu leleh 160°C, tekanan pengeoakan 60%, kecepatan sekrup 70%, waktu pengisian 2s. Polypropylene daur ulang 50% memberikan nilai kekuatan tarik sekitar 28,6 Mpa dengan 160°C, 70%, 60%, 3s. Polypropylene-nanoclay daur ulang 75% memberikan nilai kekuatan uji tarik 28,2 Mpa dengan 165°C, 60%, 70%, 3s. Polypropylene-nanoclay daur ulang 25% memberikan nilai kekuatan uji tarik sebesar 28,54 Mpa dengan 165°C, 60%, 70%, 3s. Terakhir komposisi 100% polypropylene-nanoclay daur ulang memberikan nilai kekuatan tarik 27,9 Mpa dengan suhu leleh 160°C, 70%, 50%, 1s. Setiap komposisi menunjukkan nilai kekuatan uji tarik yang berbedai sesuai dengan persentase PPNC daur ulang masing-masing.

Kata kunci: injection moulding, polypropylene, polypropylene-nanoclay

Abstract

Injection moulding is one of the most efficient process in mass production that can easily produce accurate geometry product with very short cycle time. The main purpose of this research is to analyze the effect of processing parameter on the quality of the product. Through this experiment, the parameters that are going to be used are melt temperature, packing pressure, screw speed, and filling time. The materials that will be used in this study are polypropylene and recycled polypropylene nanoclay. According to the results, 100% polypropylene give average tensile strength value around 28.5 MPa with best parameters are melt temperature 160°C, packing pressure 60%, screw speed 70%, filling time 2s. 50% recycled polypropylene give tensile strength value around 28.6 MPa with 160°C, 70%, 60%, 3s. 75% recycled polypropylene nanoclay give 28.2 MPa tensile strength value with 165°C, 60%, 70%, 3s. 25% recycled polypropylene nanoclay give 28.54 MPa tensile strength value with 165°C, 60%, 70%, 3s. The last recycled polypropylene nanoclay 100% give tensile strength value of 27.9 MPa with melt temperature 160°C, 70%, 50%,1s. Each composition for tensile shown different value according to their recycled PPNC percentage.

Keywords : injection molding, polypropylene, recycled-polypropylene

1. INTRODUCTION

PPNC is a nanocomposite, which have obtained properties improvement as high modulus, increased strength and heat resistance, decrease gas permeability, flammability so that polypropylene-nanoclay gain a lot of public interest. Generally PPNC has better mechanical and materials properties among the other virgin polymer, the modulus increases to be higher also increased strength and heat resistance, same material will acquire smaller practical material properties improvement change with various processing condition, PPCN containing 1 wt%, 3 wt%, 5 wt% and 7 wt% nanoclay have been studied before in a research about its properties, tensile strength of PPCN had expanded proportional to the expanding in nanoclay content from 0 to 5 % of weight, in content more than 5 % weight there is no significant improvement. In Dynamic Mechanical Analysis (DMA), mostly proportions of PPCN indicates high progression of the modulus as long as the researched temperature range, mostly nanoclay based nanocomposites shows reduced flammability behavior. Heat Release Rate also reduce until 50 – 75 % for PP-g-MA added nanocomposites, when compared with the conventional composites PPNC has some advantages such as PPNC is a very lightweight materials and PPNC is also more economical when compare with other material (M. H. Othman, Hasan, & Wahab, 2014).

Most of the polymer waste ends in landfills. Microbes need long time to decomposition this material because plastic/polymer is non-biodegradable. So this polymer should to recycled to clear the pollution problems, in this case is polypropylene. We know that recycled polypropylene has some problem, the reduced polypropylene is in quality and durability, physical and mechanical properties, surface appearance, and thermal properties. Therefore, recycled polypropylene should be mixed with nanoclay to improve the properties. It is of basic criticalness to effectively control all the impacting factors during manufacturing or injection molding process by precise optimization method as Taguchi method. Recently, Taguchi method become effective technique for improve the quality of part that created (Mehat & Kamaruddin, 2011).

Material characteristic, mold design and the process influence the quality of injection molding. If the design of the mold encountered an error will produce defects. Defects in dimensional stability of the parts result in shrinkage and warpage. Taguchi method use to minimize these defects to improve quality of the parts of injection molding(Altan, 2010).

2. METHOD

Flow Chart Diagram

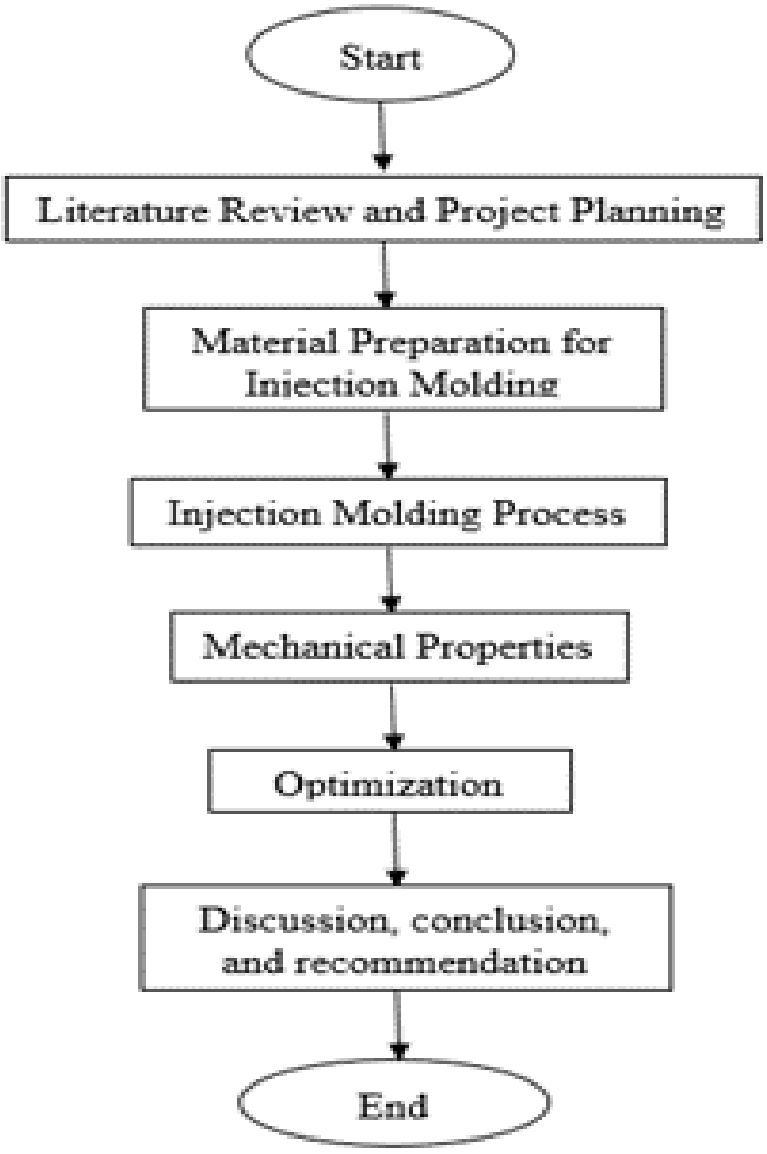

Figure 1. Flowchart Diagram

3. RESULT AND DISCUSSION

Table 1. The response values table of S/N ratio for tensile strength (Polypropylene 100%)

Level	S/N Ratio response values for Tensile strength			
	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
1	29.31	29.39	29.05	29.13
2	29.31	28.99	29.19	29.35
3	28.87	29.12	29.25	29.01
Delta	0.45	0.40	0.20	0.34

Table 1 shows the response values of Signal to Noise Ratio for tensile strength. For 100% Polypropylene based on the signal to noise ratio differences the highest and the lowest value, the most influence processing condition for tensile strength was processing temperature/melt temperature and followed by packing pressure, then filling time and the last is screw speed.

Table 1. The response values table of S/N ratio for tensile strength (Polypropylene 50% + recycled Polypropylene Nanoclay 50%)

Level	S/N Ratio response values for Tensile strength			
	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
1	29.22	29.09	29.15	29.14
2	29.16	29.19	29.21	29.04
3	29.00	29.11	29.03	29.21
Delta	0.22	0.10	0.18	0.17

Based on Table 2 that shows response values for Polypropylene 50% + recycled Polypropylene Nanoclay 50%. The most influential processing condition was melt temperature, followed by screw speed, and then filling time, the last affect processing condition for 50% recycled Polypropylene-nanoclay was packing pressure.

Table 2. The response values table of S/N ratio for tensile strength (Polypropylene 75% + recycled Polypropylene Nanoclay 25%)

Level	S/N Ratio response values for Tensile strength			
	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
1	28.88	29.05	29.01	28.98
2	29.12	29.01	28.99	29.01
3	29.06	29.00	29.07	29.07
Delta	0.24	0.05	0.08	0.09

The most influence processing condition for Polypropylene 75% + recycled Polypropylene Nanoclay 25% based on Table 3 above was melt temperature, same with recycled Polypropylene-nanoclay 50% and Polypropylene 100%, then followed by filling time, screw speed, the last influence processing condition for Polypropylene-nanoclay 25% was packing pressure.

Table 3. The response values table of S/N ratio for tensile strength (Polypropylene 25% + recycled Polypropylene Nanoclay 75%)

Level	S/N Ratio response values for Tensile strength			
	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
1	29.11	29.19	29.12	29.04
2	29.12	29.07	29.06	29.09
3	29.09	29.07	29.15	29.20
Delta	0.03	0.12	0.09	0.16

Table 4. shows the response values Signal to Noise ratio for recycled Polypropylene-nanoclay 75%. Filling time was the most influence processing condition, followed by packing pressure, then screw speed, and melt temperature was the last that affect processing condition.

Table 4. The response values table of S/N ratio for tensile strength (Polypropylene 0% + recycled Polypropylene Nanoclay 100%)

Level	S/N Ratio response values for Tensile strength			
	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
1	28.98	28.86	28.97	28.99
2	28.95	29.00	28.99	28.81
3	28.83	28.90	28.79	28.96
Delta	0.14	0.14	0.20	0.18

Based on Table 1, 2, 3, 4,5, the differences of processing parameter that most influence processing condition for every types of sample may happened because different percentage of recycled Polypropylene-nanoclay.

Signal to Noise ratio diagram had created for tensile strength based from the data for every types of sample (Polypropylene, Polypropylene 50% recycled Polypropylene-nanoclay 50%, Polypropylene 75% recycled Polypropylene-nanoclay 25%, Polypropylene 25% recycled Polypropylene-nanoclay 75%, recycled Polypropylene-nanoclay 100%) was illustrated in figure 1, 2, 3,4, 5.

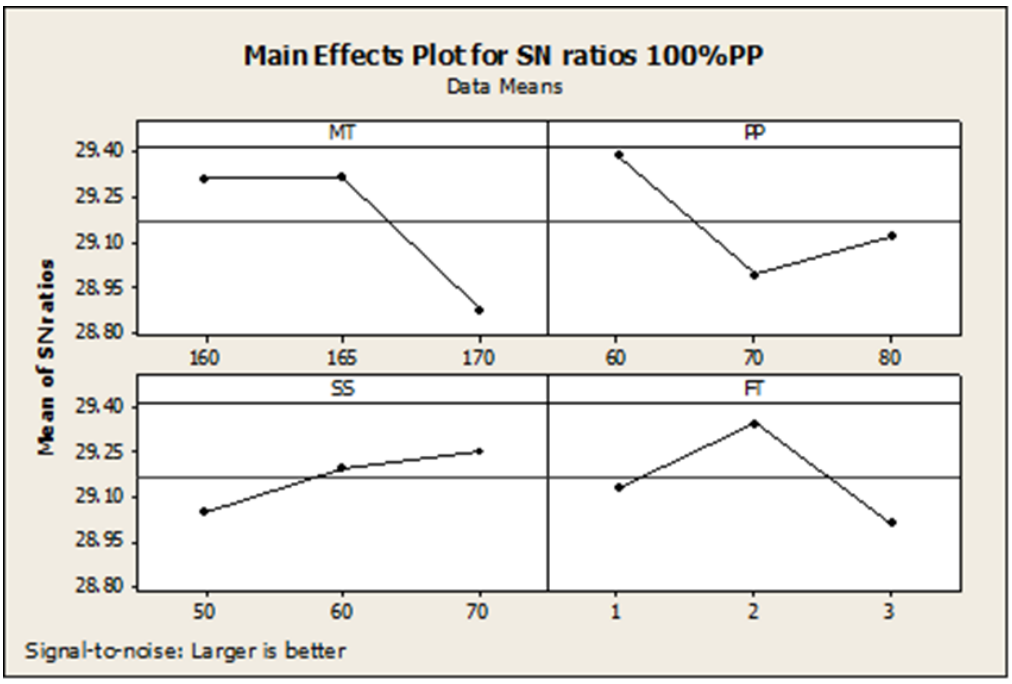

Figure 1. The tensile S/N ratio for 100% of PP

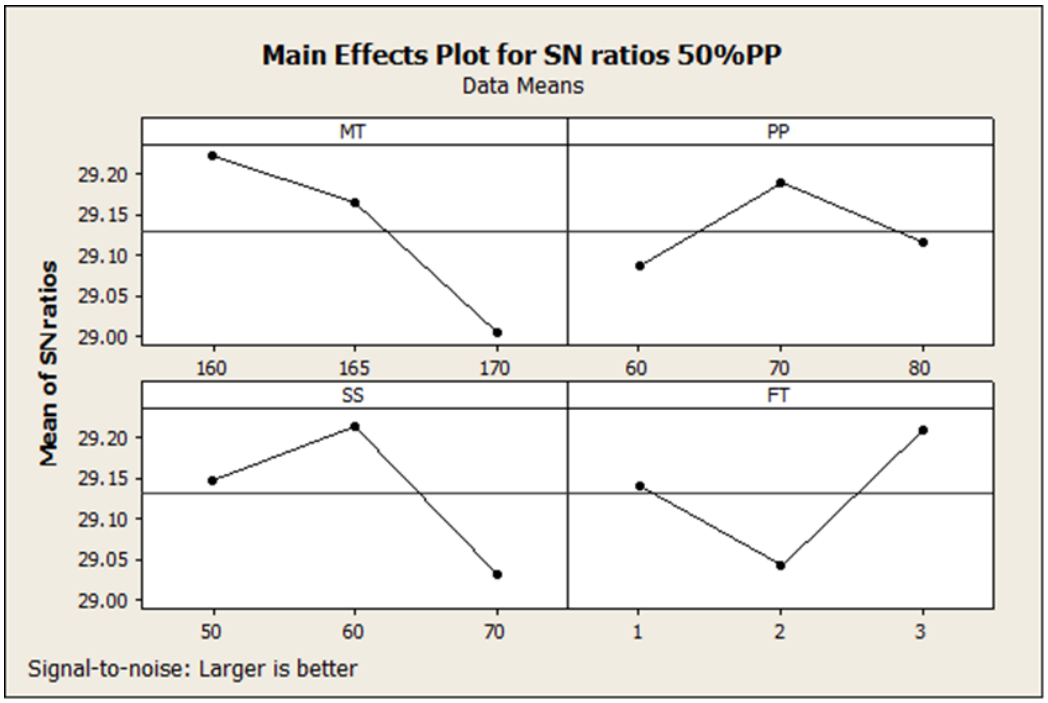

Figure 2. The tensile S/N ratio for 50% PP

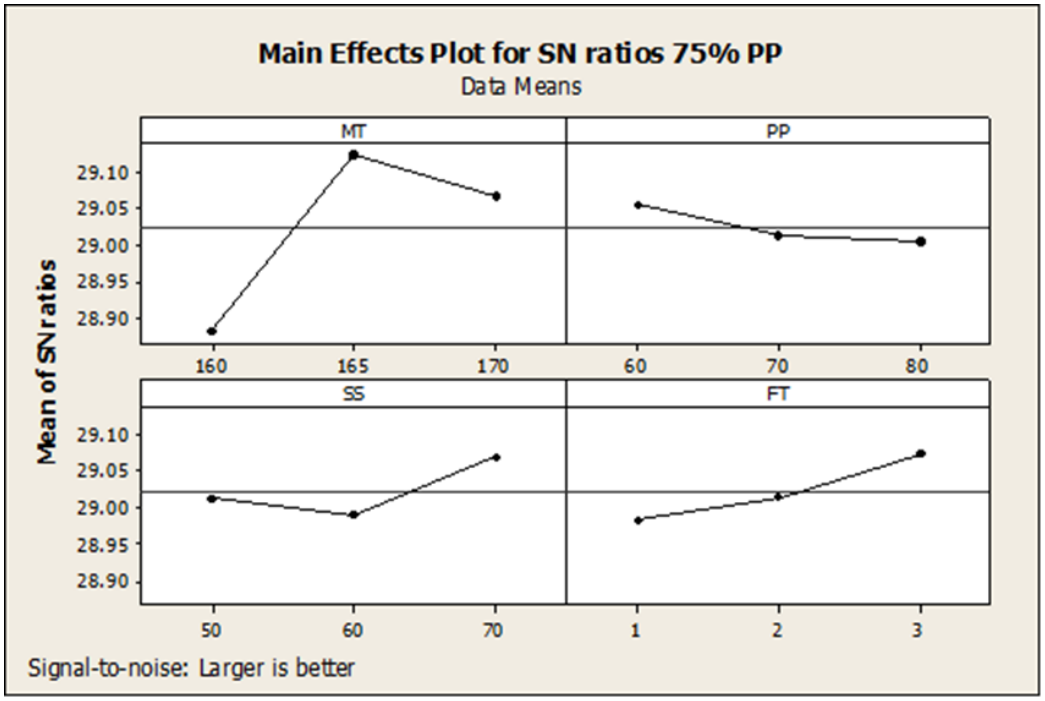

Figure 3. The tensile S/N ratio for 75% PP

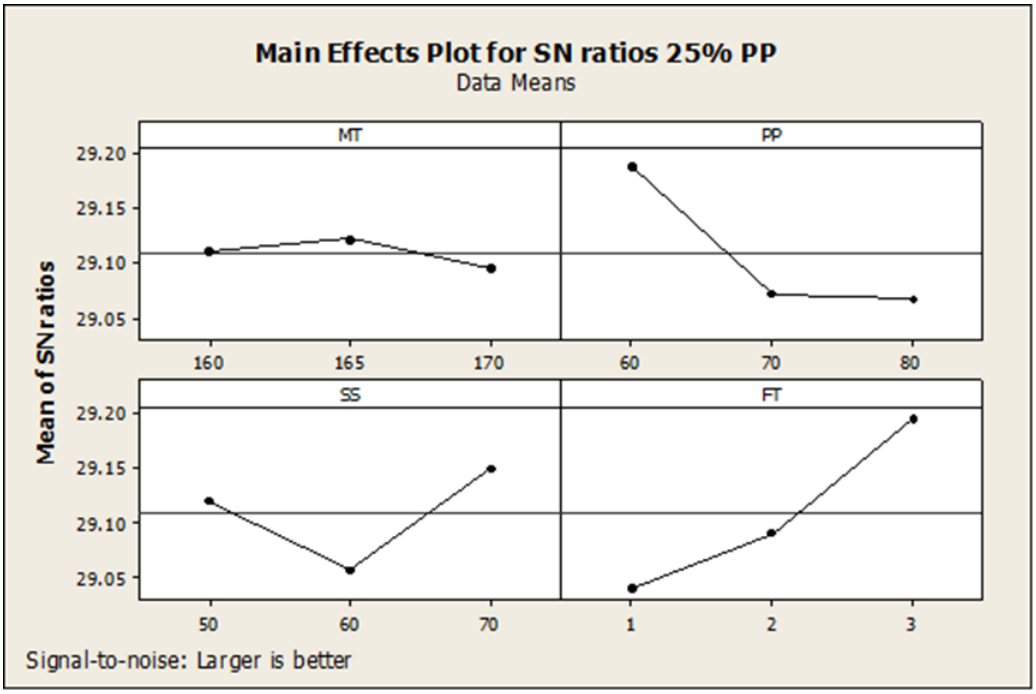

Figure 4. The tensile S/N ratio for 25% PP

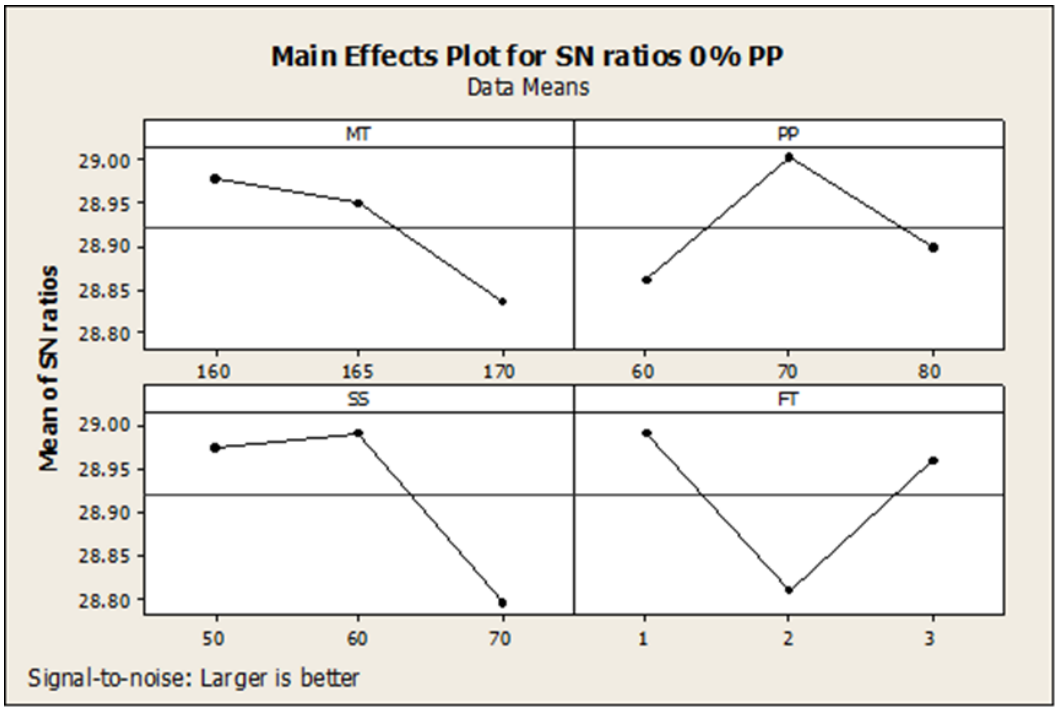

Figure 5. The tensile S/N ratio for 0% PP

By selecting level with the highest value for each factor were determined the best set of combination parameters for improving tensile strength. Therefore, the result obtained for melt temperature, packing pressure, screw speed and filling time for Polypropylene, Polypropylene 50% and recycled Polypropylene-nanoclay 50%, Polypropylene 75% and recycled Polypropylene-nanoclay 25%, Polypropylene 25% and recycled Polypropylene-nanoclay 75%, recycled Polypropylene-nanoclay 100% was shown below :

Table 5. Best combination parameter of processing condition for Polypropylene

Factor	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
Maximum S/N value (dBi)	29.31	29.39	29.25	29.35
Level	1	1	3	2
Level Value	160°C	60%	70%	2s

Hence, the best combination parameters of melt temperature, packing pressure, screw speed and injection time for Polypropylene were 160°C, 60%, 70%, and 2s respectively.

Table 6. Best combination parameter of processing condition for Polypropylene 50% and recycled Polypropylene-nanoclay 50%

Factor	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
Maximum S/N value (dBi)	29.22	29.19	29.21	29.21
Level	1	2	2	3
Level Value	160°C	70%	60%	3s

The best combination parameter of melt temperature, packing pressure, screw speed and injection time for Polypropylene 50% and recycled Polypropylene-nanoclay 50% were 160°C, 70%, 60%, 3s respectively.

Table 7. Best combination parameter of processing condition for Polypropylene 75% and recycled Polypropylene-nanoclay 25%

Factor	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
Maximum S/N value (dBi)	29.12	29.05	29.07	29.07
Level	2	1	3	3
Level Value	165°C	60%	70%	3s

The best processing condition for melt temperature was 165°C, packing pressure was 60%, screw speed was 70% and the filling time was 3s for Polypropylene 75% and recycled Polypropylene-nanoclay 25%.

Table 8. Best combination parameter of processing condition for Polypropylene 25% and recycled Polypropylene-nanoclay 75%

Factor	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
Maximum S/N value (dBi)	29.12	29.19	29.15	29.20
Level	2	1	3	3
Level Value	165°C	60%	70%	3s

The best combination parameters of melt temperature, packing pressure, screw speed and injection time for Polypropylene 25% recycled Polypropylene-nanoclay 75% were 165°C, 60%, 70% and 3s respectively.

Table 9. Best combination parameter of processing condition for Polypropylene 0% and recycled Polypropylene-nanoclay 100%

Factor	Melt Temperature	Packing Pressure	Screw Speed	Injection Time
Maximum S/N value (dBi)	28.98	29.00	28.97	28.99
Level	1	2	1	1
Level Value	160°C	70%	50%	1s

best combination parameters of melt temperature, packing pressure, screw speed and injection time for 0% Polypropylene recycled Polypropylene-nanoclay 100% were 160°C, 70%, 50% and 1s respectively.

4. CLOSING

4.1 Conclusion

In this study, optimal injection moulding conditions for maximum tensile strength determined by the Taguchi methods. Polypropylene (PP), Polypropylene 50% and recycled Polypropylene-nanoclay 50%, Polypropylene 75% and recycled Polypropylene-nanoclay 25%, Polypropylene 25% and recycled Polyprolene-nanoclay 75%, recycled Polypropylene-nanoclay 100% were injected in dumbbell shaped specimens under four processing parameters: melt temperature, packing pressure, screw speed and filling time. Taguchi's orthogonal array L9 (3^4) was used for the experiment strategy so that nine trials had run and three samples for each trial were analyze. By calculated the value of tensile strength, the best combination or optimum parameters for processing condition in order to optimise or improve the strength had analyzed in this research. The improvement calculated based on the Signal to Noise (S/N) ratio method.

The best combination parameter for processing condition by selecting level with highest value for each factor for Polypropylene, Polypropylene 50% and recycled Polypropylene-nanoclay 50%, Polypropylene 75% and recycled Polypropylene-nanoclay 25%, Polypropylene 25% and recycled Polyprolene-nanoclay 75%, recycled Polypropylene-nanoclay 100% has been obtained. In summary, it can be conclude that the objective of this research have been achieved. However, values for tensile strength does not meet the optimum value should be. So, some recommendation has been given below for more detail studies in the future.

4.2 Recommendations

Make sure the injection moulding machine is has been preheated and in good condition before running. The injection moulding machine which in the polymer laboratory is not in good condition, the temperature was not stable, clean the hopper before filling the material, remove the remaining material inside the barrel, there are

still some material left from the last process. This will produce poor quality products.Clean the granulator machine that is use to crush the recycled Polypropylene-nanoclay product by using air compressor and brush. This is to make sure there are nothing other material that contained in the experiment.Different mixture composition of Polypropylene and recycled polypropylene nanolay can be used so that the effects of processing parameters will be analyze and study in the future.Use different factor level of processing condition, in order to achieve the best value of tensile strength.

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